the techniques discussed in commonly-assigned U.S. Patent Application Nos. 09/472,162, filed December 27, 1999, and 09/609,919, filed July 3, 2000.

[43] Various types of camera-motion layers are possible, including static camera-motion layers, video camera-motion layers, and animation camera-motion layers. For a static camera-motion layer, the layer is an image that is warped in accordance with the camera motion parameters, thereby giving the illusion of motion.

[44] For a video camera-motion layer, the video camera-motion layer can be a video itself. The time and space extents of the video camera-motion layer govern when and where the video camera-motion layer appears in the composite video sequence. The frames of the video camera-motion layer are synchronized with frames of the composite video sequence. The camera motion parameters govern how each frame of the video sequence is warped into the geometry of the composite video sequence.

[45] For an animation camera-motion layer, the animation camera-motion layer can be an animation itself. The animation can be an animation in any format useful for defining animation. Examples of such formats include Flash and animated GIF. The time and space extents of the animation camera-motion layer govern when and where the animation camera-motion layer appears in the composite video sequence. The frames of the animation camera-motion layer are synchronized with frames of the composite video sequence. The camera motion parameters govern how each frame of the animation is warped into the geometry of the composite video sequence.

[46] Camera-motion layers have camera motion parameters associated with each frame, which allow the camera-motion layers to appear to move as the camera moves. This is accomplished by warping the image data into the coordinate system of each successive frame

according to the camera motion parameters. With the camera motion parameters, the camera motion gives a consistent motion view with respect to a moving camera. The camera motion parameters of the camera-motion layers for a particular frame can be the same or different.

[47] The camera motion parameters dictate the camera movement with respect to the camera-motion layers. The camera motion parameters specify the mathematical relationship between one coordinate system and another. Here, the camera motion parameters specify the coordinate transformation from the image plane of the camera-motion layer to the image plane of the video frame. Camera motion parameters dictate, for example, pan, zoom, tilt, and roll of the camera. Camera motion parameters can be specified in a number of mathematically equivalent ways. For example, camera motion parameters can be expressed as a homogeneous 3x3 matrix M, where

$$\begin{bmatrix} u \\ v \\ f \end{bmatrix} = M \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

such that $(u/f, v/f)$ are coordinates in the image plane of the video frame, and (x, y) are the coordinates in the image plane of the camera-motion layer. As another example, camera motion parameters can be expressed as a list of numbers corresponding to analytical parameters such as the three rotational angles, three translational offsets, and a scale change.

[48] The fixed-frame layers are fixed with respect to the video frame. The fixed-frame layers can be considered to be in the foreground of a frame, but they are not necessarily always in what a viewer would refer to as the foreground. The fixed-frame layers generally correspond to the foreground of a video frame, but they are not limited to being in the foreground. Each fixed-frame layer has separate information content for each frame. The fixed-frame layers are represented in two-dimensional space. As an example, the foreground regions discussed above

can be considered to be a fixed-frame layers. As another example, with the MPEG-4 international standard for representing digital video, the video object layers (VOL) can be considered to be fixed-frame layers. As a further example, an original video sequence can be decomposed into a decomposed original video sequence having original fixed-frame layers using the techniques discussed in commonly-assigned U.S. Patent Application Nos. 09/472,162, filed December 27, 1999, and 09/609,919, filed July 3, 2000.

[49] Camera-motion layers and fixed-frame layers have a number of similar attributes. For example, both types of layers have extent in time and space. With respect to time, both types of layers can have on/off times. An on/off time indicates when a particular layer is part of the composite video stream and when it is not. A particular layer can have zero or more on/off times. With respect to space, both types of layers can be a full rectangular frame or an arbitrarily shaped region having an area greater than or less than a frame. Both types of layers can have varying degrees of opaqueness, which is the inverse of transparency. Further, each layer can have a relative ordering with respect to the other layers. The ordering of the layers dictates the precedence of one layer with respect to the other layers (e.g., which layer occludes which other layers).

[50] In block 13, one or more original camera-motion layers are edited by the video editor 4, which results in one or more modified camera-motion layers. Each original camera-motion layer either can be edited as an original camera-motion layer or can be edited by converting the original camera-motion layer to an image and editing the image, as discussed below with respect to Figure 3. Further, various techniques are available for editing the original camera-motion layers, as discussed below with respect to Figure 4.